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Operating the Irish Power System with Increased Levels of Wind Power

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Abstract— This paper summarises some of the main impacts of large amounts of wind power installed in the island of Ireland. Using results from various studies performed on this system, it is shown that wind power will impact on all time frames, from seconds to daily planning of the system operation. Results from studies examining operation of the system with up to approximately 40% of electricity provided by wind show that some of the most important aspects to be considered include the type of wind turbine technology, the provision of reserve to accommodate wind forecasting error and the method used to plan plant schedules.

I. INTRODUCTION

In the past decade, there has been a large increase in the number of installed wind turbines in a number of countries, e.g. Denmark, Germany, Spain. Other countries are also planning on increasing the amounts of wind power installed to meet renewable energy targets, e.g. Ireland, Great Britain. High levels of installed wind power will have implications for the operation of power systems. These will be seen on different timescales, from seconds (i.e. frequency and inertia issues) to hours (i.e. unit commitment and dispatch) to years (transmission planning, system adequacy). Much work is currently being done to examine possible impacts of incorporating wind power into operation of power systems [1]. In this paper, issues arising from the increased levels of installed wind power on the operation of the Irish system will be examined.

Wind power is seen as one of the major contributors to Ireland's renewable energy targets - the Republic of Ireland plans to be producing 15% of electricity consumption by renewable sources by 2010 and 33% by 2020 [2]. This means that approximately 6GW of wind could be installed on the Irish system by 2020, out of a total of approximately 14GW of installed capacity. There is currently approximately 800MW of installed wind power on the Irish system. While these targets for wind power would constitute a challenge for any system, the fact that Ireland is isolated and weakly interconnected, with only 500MW of interconnection to Great Britain currently in

operation and another 500MW planned to be built, means that many of the challenges associated with high wind penetration will be more significant in Ireland. In the past year, Ireland has moved from being two separately operated systems to a single electricity market, comprising Northern Ireland and the Republic of Ireland [3]- it is this single system that is considered here.

II. SUMMARY OF STUDIES ON OPERATIONAL ISSUES IN IRELAND

This section summarizes a number of studies relating to operation of the Irish power system with increasing wind power. A summary of the methods used is provided, as well as significant results.

A. Impact of wind power on inertia and frequency

As the all-Ireland system is weakly interconnected, the effect of increasing amounts of wind power on system inertia is greater than can be seen on other systems of similar size with stronger interconnection. As the system inertia in isolated systems is lower, the frequency change will be faster if load or generation changes. In [4], Lalor *et al* examined the impact of increased wind penetration on frequency control in Ireland. A system model was used to examine the response of the frequency of the Irish system to imbalances in supply and demand. Three different scenarios - winter peak, summer night valley and summer day valley were examined for a range of installed wind power from 0MW to 2000MW. Two different wind turbine technologies were included - fixed speed and doubly-fed induction generators (DFIG). It was found that rates of change of frequency will increase as wind penetration grows, regardless of technology used. While fixed speed machines have no significant impact on minimum frequency reached after loss of generation, DFIGs reduce the frequency nadir. Therefore, the type of installed wind power will have an impact on the provision of reserve, particularly in an isolated system as Ireland is. As installed wind power is increased beyond the 2000MW considered in this study, the effect on frequency will be more significant, and could lead to new operating methods to ensure system inertia is kept at a high enough level.

B. Increase in reserve requirements

One of the major challenges facing system operators when considering increased wind penetration is the provision and

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calculation of system reserve. With low levels of installed wind, and therefore accurate knowledge of supply available, the amount of reserve carried will be enough to cater for the loss of the largest infeed. As the amount of wind increases, its unpredictable nature means that this will no longer be sufficient, as an unforecasted change in output may cause load to be shed. To maintain system reliability at current levels, extra reserve needs to be carried. In [5], the additional system reserve needed for a significant amount of installed wind power is quantified, using the Irish system as a test case. This uses a probabilistic approach that accounts for the uncertain nature of wind power production, as well as generator outage rates and demand forecasts. Using the number of load shedding incidents per year as the reliability criterion, the additional reserve needed as wind power penetration grows is quantified. The method proposed in [5] is applied to the Irish system for installed wind power capacities of 0MW to 2000MW.

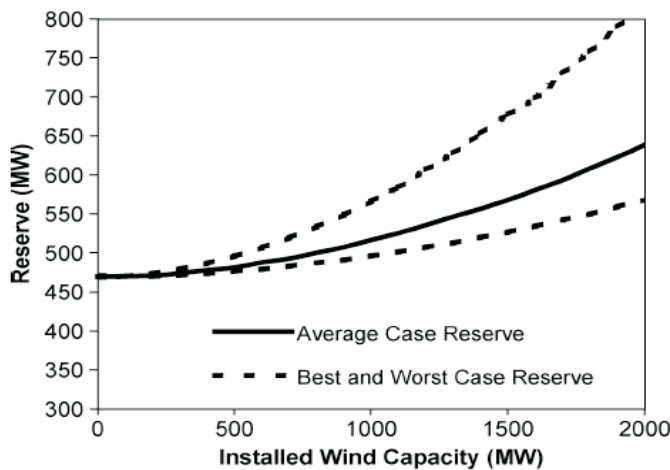


Fig. 1. Reserve requirement for increasing wind power with a reliability level of 3 load shedding incidents per year - taken from [5]

From this work, it can be seen that increasing wind penetration causes an increase in the reserve requirements of the system. Figure 1 shows the increase in reserve for increasing levels of wind penetration with a forecast horizon of three hours, and different assumptions about the performance of wind forecasting. [5] also showed that the increase in demand for fast acting reserves is minimal for these levels of wind penetration, due to the small nature of wind power variations. The longer acting reserve can be seen to increase as wind penetration increases, and also when committing reserve with a large forecast horizon, i.e. several hours before the hour in question.

C. Managing variability of wind

Unit commitment optimises planned generation to meet demand at lowest cost. This takes into account the characteristics of the units such as start up time and costs, minimum up and down times and ramping rates. Methods currently in use are well established [6]. With low levels of wind power on the system, wind can be ignored and conventional unit

commitment methods used to plan schedules, before being readjusted when operating the system with wind - this is described as the fuelsaver method in [7]. However, when wind power penetration increases, this will lead to more units being online than needed, and units not operating efficiently. A more optimal approach uses wind forecasts when scheduling the system, and carries reserve based on the expected error of these forecasts, as described in section II-B. By explicitly taking into account the stochastic nature of wind, more robust solutions can be provided, which will take into account numerous possible scenarios for wind power production.

The all island grid study was established by the governments of Ireland and Northern Ireland to examine the integration of high levels of renewable energy on the Irish grid around the year 2020. Workstream 2A [8] provided possible plant portfolios for 2020 based on expected demand growth, fuel price scenarios and carbon costs. These portfolios produced figures for installed wind power varying from 2000MW to 8000MW, which correspond to approximately 11% to 44% of total production on the system. Workstream 2B [9] examined the planning of units that would be expected for these portfolios. This was done using the Wilmar planning tool, a planning tool developed to analyze the integration of wind in liberalised energy markets [10]. This is a stochastic planning tool which uses a mixed integer solver to solve for unit commitment. It uses rolling planning, whereby the planned unit schedules are updated every 3 hours as more precise wind and demand forecasts become available. It adopts a multi-stage approach, where the first stage covers 'here-and-now' decisions, i.e. decisions to be made between one rolling planning period and the next. The other stages cover 'wait-and-see' decisions, where a robust solution is provided which covers multiple outcomes for wind and demand. In the 'here-and-now' stage, perfect forecasting is assumed as this represents decisions that are made to cover the hours between one decision time and the next. While this means that this planning tool will not give completely realistic operating results, it does give indications of the impact of wind power on operating decisions.

Several results can be taken from this study regarding the possible operation of the Irish power system with high levels of wind power. They are explained in more detail in [9], and summarised here. Firstly, as would be expected, total operating costs over the year decrease as wind power penetration increases. By increasing the amount of wind power from 2000MW to 6000MW, the total costs of the Irish system, plus the net import cost, can be seen to decrease by approximately 31%. 3 portfolios were examined with the same amount of installed wind, with the mix of conventional plant changing. Here, it was found that, even though Open Cycle Gas Turbines offer more flexibility due to faster starting and ramping times, the plant mix with less of these but more of the slower acting, baseloaded Combined Cycle Gas Turbine was less expensive. The cost savings that would be made if wind was perfectly predictable were also shown, and varied from 0.05% of total system costs for the portfolio with 2000MW of installed wind, to 3.4% for the portfolio with 8000MW of wind installed.

As regards the expected benefits of increasing wind power on the Irish system, [11] uses a dispatch model to provide

a cost benefit analysis of wind power. Here, it is found that increased interconnection, high CO₂ prices and a flexible plant mix are beneficial for wind generation. There are positive net benefits for wind energy penetrations of 17% and greater on the Irish system.

D. The impact of uncertainty of wind power on the Irish system

As wind power on the system grows, the effect of the uncertainty associated with wind forecasting will also become more obvious. The Wilmar planning tool described in the previous section shows that as wind penetration increases, the operation of units on the system changes. This planning tool assumes a certain amount of perfect forecasting, which is unrealistic. By changing the amount of uncertainty being accounted for, the impact of this uncertainty on the operation of the system can be deduced. In [12] the length of the first stage of the scenario tree is changed. This is the stage which models 'here-and-now' decisions between one planning loop and the next. Changing the length of the first stage has the effect of changing the time that perfect forecasting is assumed in the model. As the length of the stage shortens, more uncertainty is included in the model, therefore results closer to realistic operation of the system are found, and the impact of uncertainty of wind on the likely operation of the system can be seen.

From [12], increasing uncertainty in the model can be seen to increase the total expected costs. The fast acting units are used more as uncertainty is increased. [12] also shows the benefit of using stochastic programming methods to optimise the system. When comparing the total expected costs produced by schedules based on the same wind forecasts, the schedules produced when using stochastic optimisation prove to be less expensive than those produced when deterministic optimisation is used. This is due to the fact that the stochastic methods produce more robust schedules which can react accordingly to the uncertain nature of wind power.

III. DISCUSSION

The previous section outlines some of the most significant impacts that increased wind penetration will have on the Irish power system. In the shorter time scale, the low system inertia of the relatively isolated Irish system means that an important challenge will be to ensure the frequency remains stable. It should be noted that [4] only studies the Irish system for installed wind power up to 2000MW, which, while similar to the amount needed by 2012 to ensure Ireland meets its 15% target for renewables, is much lower than the possible 6000MW envisaged for 2020. Therefore, the low system inertia will have a greater impact than that described. This will require changes to the operating practice of the system as more wind is installed. [5] also examines the Irish system for levels of installed wind power to 2000MW. Therefore, as more is installed, the reserve requirement due to the forecasted wind will start to increase to the level where it is nearly as large as the reserve needed to cover loss of the largest infeed. From sections II-C and II-D, it can be seen that wind forecasting,

and how it is managed, will prove to be important, both in terms of overall systems costs, and the operation of individual units. It has also shown the fact that, while large amounts of wind power will cause changes to the methods used to operate the system, it is nonetheless possible to operate the Irish system with wind providing up to 40% of total electricity requirements.



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